Occupational exposure levels to wood dust in Italy, 1996–2006

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ABSTRACT

Background: Wood dust has been classified as carcinogenic to humans and the association with nasal cancer risk has been observed in a large number of epidemiological studies.

Objectives: The aim of this study is to summarise data about occupational exposure levels to wood dust in Italy and to examine some exposure determinants.

Methods: Exposure measurements on wood dust were extracted from the SIREP (Italian Information System on Occupational Exposure to Carcinogens) database between 1996–2006. Descriptive statistics were calculated for exposure-related variables using univariate analyses. The prevalence of elevated exposure levels was estimated overall and for some industrial sectors. A multifactorial analysis of variance was performed to determine which factors influenced exposure levels to wood dust.

Results: The total number of exposure measurements (n) reported is 10 837, which refer to 10 528 workers and 1181 companies. The overall arithmetic mean is 1.44 mg/m^3 and the geometric mean is 0.97 mg/m^3. Industrial sectors at high risk are "manufacture of wood and wood products" (n = 5539) as well as "manufacture of furniture" (n = 4347). About 74% of exposure measurements report a value <2 mg/m^3. In the multifactorial analysis, it has been found that job category, industrial sector, company size and geographical location of the company influence the exposure levels.

Conclusions: This study confirms the previous findings about occupational exposure to wood dust (mainly in wood industry and among woodworking machine operators) and suggests further investigations on other risk sectors (building and repairing of ships and boats). The potential of the occupational exposure database as a source of data for exposure assessment and surveillance is also confirmed.

Wood dust has been classified in group 1 as carcinogenic to humans[1] and its association with cancer risk of the nasal cavities and paranasal sinuses has been observed in a large number of epidemiological studies in different countries. The first association between cancer and wood-related jobs was found in 1965 in Britain among male woodworkers.[2] Several other studies have shown that wood dust-related cancer risk is the highest for nasal adenocarcinoma,[3] particularly among European populations. Other types of nasal cancer and cancers at other sites have been associated with the exposure to wood dust, but the overall epidemiological evidence is not yet strong enough.[4] Some studies have suggested a risk increase among exposed workers for cancer of the nasopharynx,[5] larynx,[6] lung[7] and Hodgkin's disease.[8]

Wood dust is generally classified into two categories: dust from "softwood" which is a wood cheap to produce and easy to work, such as pine; and dust from "hardwood" which is hard heavy wood mostly from deciduous trees. The European Union has recognised hardwood dust as a carcinogen and has set the occupational exposure limit (OEL) to 5 mg of inhalable dust in cubic metre of workroom air (Directive no 1999/38/EC). Studies on particle-size distribution have shown that the highest proportion of airborne wood dust is represented by particles larger than 10 μm, which can be caught in the nasal passages.[9 10] Wood dust is created during the cutting and shaping of wood materials and its composition varies according to tree species. The worst health effect has been observed for sinonasal cancer among workers exposed to oak and beech wood.[11] The wood and furniture industry are the most involved sectors, with particular reference to sawmills, planing mills, cabinet manufacture and construction carpentry.[1] In 2001 the European research project "Risk assessment of wood dust: assessment of exposure, health effects and biological mechanisms" was launched with the aim of assessing exposure to wood dust and investigating biological mechanisms related to health effects. An occupational exposure database (WOODEX), reporting relevant data on wood-dust exposure in 25 member states of the EU, was developed within this project. This database provides the estimates of exposure to inhalable wood dust by country and industry, level of exposure and type of wood, and reports 0.5 million workers in the EU possibly exposed to a dust level exceeding 5 mg/m^3.[12]

The age-standardised incidence rate (cases per 100 000 per year) for cancer of the nasal cavities in Italy ranges between 0.4–2.0 (n = 336) in men and 0.1–0.5 (n = 141) in women, in the period 1998–2002.[13] This cancer site is rare and, apart from hardwood dust, it is related to leather dust occupational exposure.[14] Other supposed aetiological factors for nasal cancer are exposure to formaldehyde,[1] chromates and nickel compounds,[15] even if the epidemiological evidence is still limited. The Italian legislative decree no 626 of 19 September 1994 and subsequent integrations, were initiated as a consequence of the EU Directive concerning occupational carcinogenic and mutagenic agents, have enforced preventive measures for hardwood-dust exposure and established an exposed workers register. On this basis, the Italian Institute for Occupational Safety and Prevention (ISPESL) has developed a database system, SIREP (Information System for Recording Occupational Exposures to Carcinogens), in order to collect data regarding occupational exposure to carcinogenic agents.

The aim of this study is to summarise data, stored in the SIREP database, about occupational exposure levels to wood dust in Italy in the period 1996–2006. Workplace features and companies' characteristics have been evaluated to investigate the determinants of exposure level. Moreover, problems that arose in coding of exposure variables, as well as possible misclassifications, have been discussed.

METHODS

Data on exposure to carcinogens are collected by employers and regularly sent (every three years) to ISPESL, according to the Italian legislative decree no 626 of 19 September 1994. Such information, called "exposure registries", includes quantitative measurements of exposure and has been collected since 1996. The core information, in accordance with the indications of the European working group on the measurements of exposures in workplaces,[16] is: corporate name, territorial location of the firm, economic activity sector and company size; last name, first name, sex and date of birth of each worker; job title and occupation of the worker; and the exposure level to wood dust (intensity, frequency and duration). Companies are responsible for collecting the exposure measurements in accordance with the EN 689:1995 regulation by the European Committee on Standardization.[17] Several guidelines have been implemented to assist companies in complying with the law (for example, http://www.ispesl.it/linee_guida/aggiornamenti/linee_guida_legno_duro.pdf, last access 10 October 2007, in Italian).

Data are recorded in a database (SIREP) with a relational structure and realised in Oracle (version 10) for Microsoft Windows Server 2003 operating system. The specific design has been described elsewhere.[18] SIREP has been planned for research purposes in order to prevent carcinogenic risk exposure in workplaces. A software application was developed in Microsoft Visual Basic (version 6.0) to store information from the registries in the SIREP database and a service of data-entry was used to record data. A training session was organised to familiarise the data-entry personnel with the SIREP coding system.

For the purpose of this research, information about exposure registries to wood dust recorded in SIREP from 1996 up to December 2006 was selected. Only 65% of the registries were used, while the remaining 35% were discarded for lack of core information or compilation errors, especially in the exposure section. In this study, the expression "exposure measurement" corresponds to a single value assessed from several consecutive samples. If repeated exposure measurements were reported for the same worker doing the same job, the "worst case exposure level" was considered—that is, working under the most conservative hypothesis for the protection of the worker's health. The airborne wood-dust concentrations were measured as 8-hour time-weighted average (TWA-8) and were related to exposure to hardwood dust or to mixed wood dust. Values reported below a detection limit (<0.1 mg/m^3) were replaced by the detection limit divided by two (about 6% of exposure measurements).[19] Information about the sampling type of the measuring (personal, stationary or source-oriented) and the sampling strategy (random, systematic, etc) was almost never available. The norm, however, recommends collecting air samples near the worker's "breathing zone". No data were available on sampling conditions and rarely on the use of personal protective equipment. The major species of hardwood used in Italy are poplar, beech and oak, but in most cases information on different species of wood processed could not be retrieved, since the Italian law does not provide specific rules in this regard (reported in only 1% of the documentation sent to ISPESL).

Job categories were coded using the 1991 classification of occupations (CP91) of the Italian Institute for Statistics (ISTAT), which is in line with the International Standard Classification of Occupations (ISCO-88) of the International Labour Organization. The translation activity was done using tables published on the ISTAT website (available at: http://www.istat.it/strumenti/definisioni/professioni/05raccordi.pdf, last access 28 September 2007, in Italian). The NACE Revision 1 classification of the EU was used to code economic activity sectors. Such classifications were selected according to their level of detail and frequent use.

A descriptive statistical analysis was performed to estimate mean exposure levels (arithmetic and geometric) and variability measures (geometric standard deviation and 5th–95th percentile range) by activity sector, by gender and job category, and by activity sector and job category. The prevalence of elevated exposure levels to wood dust was estimated both overall and for some industrial sectors.

A non-parametric "one-way" analysis of variance (ANOVA) with further Kruskal-Wallis test was applied to determine which variables influenced the exposure level, assumed as dependent variable, to allow a simultaneous "comparison" for more variables and to indicate whether at least one differs significantly from the others. Activity sector, company size (classified in six classes: "1–5" exposed workers, "5–10", "10–20", "20–50", "50–100", "100+"), geographical location of the company ("north east", "north west", "centre", "south and islands"), urbanisation degree of company's residence municipality ("urban", "semi-urban", "semi-rural", "rural"), worker's gender, job category and first year of exposure were all considered as independent variables. The eta squared (η^2) statistic was computed for each independent variable to measure the degree of association.

A mixed effects model with random company-specific intercepts was adopted to evaluate the association between exposure variables (which were statistically significant in the univariate analysis) and exposure concentrations. This model allowed us to account for fixed effects as well as random effects, and to handle unbalanced data. Exposure measurements were natural log-transformed because data were positively skewed and approximately log-normal distributed, and all p values were based on two-sided tests at the $\alpha = 0.05$ level. Estimation method used in the mixed model was the restricted maximum likelihood method and R^2 was calculated by the likelihood ratio test.[20]

The mixed-effects model is described by the following equation:

$\ln(Y_i) = (\text{fixed effects}) + (\text{company effect})_i + (\text{error})_i$

for $i = 1,..,n$ (companies), where Y_i is the exposure level. The model assumptions are: random effect corresponding to company (company effect) is approximately normally distributed with mean 0 and variance σ_B^2; residual (error) is approximately normally distributed with mean 0 and variance σ_W^2; and (company effect) and (error) are statistically independent. The η^2 value was computed for each specific effect from significance test statistics using the following formula:

$\eta^2 = F_{effect}(DF_{effect})/F_{effect}(DF_{effect})+DF_{error}$

No analysis was carried out on the duration of exposure or calendar periods of employment. Statistical analyses were performed by using SAS software (version 9.1).

RESULTS

The SIREP database contains records from 1822 companies and 11 322 exposed workers to wood dust, collected up to 31 December 2006. A total of 641 companies with missing

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Table 1 Number of companies, workers, and measurements, arithmetic mean (AM) and geometric mean (GM) by economic activity branch, SIREP (1996–2006)

Economic activity branch*	No of companies	No of workers	No of measurements†	AM	GM
Agriculture, hunting and forestry (A)	4	24	24	1.83	1.76
Manufacture of textiles and textile products (DB)	2	17	17	2.29	2.26
Manufacture of leather and leather products (DC)	1	13	13	0.57	0.57
Manufacture of wood and wood products (DD)	557	5342	5539	1.39	0.93
Sawmilling and planning of wood; impregnation of wood (20.1)	168	1488	1517	1.36	0.92
Manufacture of veneer sheets; manufacture of plywood, laminboard, etc (20.2)	29	425	426	1.05	0.79
Manufacture of builders' carpentry and joinery (20.3)	193	1754	1803	1.52	0.97
Manufacture of wooden containers (20.4)	12	85	85	1.89	1.21
Manufacture of other products of wood; manufacture of articles of cork, etc (20.5)	122	1248	1294	1.47	1.08
Manufacture of pulp, paper and paper products; publishing and printing (DE)	1	31	31	0.73	0.64
Manufacture of chemicals, chemical products and man-made fibres (DG)	1	1	1	0.05	0.05
Manufacture of rubber and plastic products (DH)	3	10	10	0.46	0.36
Manufacture of other non-metallic mineral products (DI)	2	6	8	0.36	0.26
Manufacture of basic metals and fabricated metal products (DJ)	9	29	29	1.18	0.97
Manufacture of machinery and equipment not elsewhere classified (DK)	4	81	81	1.74	1.21
Manufacture of electrical and optical equipment (DL)	1	3	3	2.90	2.90
Manufacture of transport equipment (DM)	40	478	496	1.84	1.37
Manufacturing not elsewhere classified, including furniture, recycling, etc. (DN)	526	4310	4401	1.46	0.97
Manufacture of furniture (36.1)	519	4256	4347	1.47	0.97
Electricity, gas and water supply (E)	1	14	14	1.53	1.52
Construction (F)	7	30	31	1.39	1.10
Wholesale and retail trade; repair of motor vehicles, motorcycles, etc (G)	13	100	100	1.32	0.99
Real estate, renting and business activities (K)	5	19	19	1.49	1.43
Public administration and defence; compulsory social security (L)	2	13	13	1.14	0.63
Other community, social and personal service activities (O)	2	7	7	2.40	2.38
All	1181	10 528	10 837	1.44	0.97

*NACE codes in parentheses; †Number of TWA-8 exposure measurements of wood dust (mg/m³). DD and DN sections are further disaggregated in the main sectors.

exposure information were excluded and the remaining 10 837 exposure measurements, referring to 10 528 workers and 1181 companies, were used in the analysis. Table 1 shows the distribution of companies, exposed workers, measurements and mean exposure levels by economic activity branch (NACE section codes). The mean exposure levels by gender and job category (ISCO-88 4 digit codes) are reported in table 2, and the mean exposure levels by activity sector and job category (NACE 3 digit and ISCO-88 4 digit codes) in table 3.

The overall arithmetic mean (AM) is 1.44 mg/m^3, the geometric mean (GM) is 0.97 mg/m^3, the geometric standard deviation (GSD) is 1.61 and the 5th–95th percentile range is 0.15–3.80. The highest numbers of recorded companies and workers (about 92%) are in the industrial sectors of manufacture of wood and wood products (NACE section: DD) and manufacturing not classified elsewhere, including furniture and recycling (NACE section: DN). Among sectors with elevated exposure measurements ($n>100$) the highest mean concentration of wood-dust results for manufacture of transport equipment (NACE section: DM; see table 1).

With regard to job category (men and women together), the most frequent exposures are reported for woodworking machine setters and setter-operators (ISCO-88: 7423; 50% of exposures; AM = 1.59, GM = 1.11, GSD = 1.70), wood-products machine operators (ISCO-88: 8240; 26% of exposures; AM = 1.24, GM = 0.83, GSD = 1.27) and wood and related products assemblers (ISCO-88: 8285; 7% of exposures; AM = 1.33, GM = 0.80, GSD = 1.70). Within these categories the job titles with high exposure are the machine-operator that shaves wood (n = 317; AM = 2.04 mg/m^3; GM = 1.43 mg/m^3; GSD = 2.62) and the wood sawyer (n = 149; AM = 1.82 mg/m^3; GM = 1.37 mg/m^3; GSD = 1.57).

The mean wood-dust concentrations measured is 1.48 mg/m^3 in male workers and 1.25 mg/m^3 in female workers. According to gender, the job category with the highest GM value is wood-processing-plant operators (ISCO-88: 8141; GM = 1.38 in men; GM = 1.09 in women), with a greater variability for men as indicated by GSD values. The lowest wood-dust exposure is experienced by manufacturing labourers (ISCO-88: 9320; GM = 0.42 in men; GM = 0.42 in women; see table 2).

Measurements by activity sector and job category give the highest GM value for building and repairing of ships and boats (NACE: 35.1) in which the job categories with the highest exposure levels are the woodworking machine setters and setter-operators (ISCO-88: 7423) as well as the carpenters and joiners (ISCO-88: 7124; see table 3).

Table 2 Arithmetic mean (AM), geometric mean (GM), geometric standard deviation (GSD) and 5th–95th percentile of exposure measurements of wood dust (mg/m³) by gender and job category, SIREP (1996–2006)

Job category* (ISCO-88 code)	No†	AM	GM	GSD	5th centile–95th centile
Men: all wood-related	9210	1.48	0.99	1.66	0.15–3.80
Wood-processing-plant operators (8141)	252	2.08	1.38	2.91	0.20–4.50
Industrial robot operators (8170)	118	1.93	1.27	2.45	0.09–3.60
Carpenters and joiners (7124)	148	1.72	1.20	1.90	0.25–3.80
Woodworking machine setters, and setter-operators (7423)	4585	1.62	1.12	1.74	0.20–4.00
Basketry weavers, brush makers and related workers (7424)	109	1.50	1.03	2.28	0.21–4.70
Wood and related products assemblers (8285)	621	1.38	0.84	1.70	0.12–3.90
Transport labourers and freight handlers (9330)	49	1.30	0.93	0.85	0.30–2.70
Wood-products machine operators (8240)	2525	1.26	0.84	1.33	0.10–3.49
Floor layers and tile setters (7132)	56	1.12	1.05	0.19	0.62–1.80
Painters and related workers (7141)	50	0.97	0.72	0.75	0.22–2.17
Stock clerks (4131)	127	0.87	0.56	0.93	0.18–2.44
Industrial-machinery mechanics and fitters (7233)	67	0.85	0.63	0.55	0.20–2.80
Machine-tool setters and setter-operators (7223)	88	0.70	0.56	0.25	0.18–1.40
Manufacturing labourers (9320)	84	0.68	0.42	0.62	0.10–3.20
Women: all wood-related	1627	1.25	0.87	1.26	0.19–3.70
Woodworking machine setters, and setter-operators (7423)	801	1.43	1.04	1.42	0.20–4.10
Wood-processing-plant operators (8141)	141	1.41	1.09	1.26	0.20–3.88
Wood and related products assemblers (8285)	102	1.04	0.57	1.53	0.10–3.90
Wood-products machine operators (8240)	322	1.03	0.73	0.75	0.10–2.70
Machine-tool setters and setter-operators (7223)	75	0.91	0.69	0.75	0.41–3.20
Manufacturing labourers (9320)	50	0.50	0.42	0.14	0.20–1.65
All wood-related	10 837	1.44	0.97	1.61	0.15–3.80

*The job categories with the highest and lowest arithmetic mean where at least 50 exposure measurements were available; †Number of TWA-8 exposure measurements.

The threshold value limit for professional exposure to inhalable hardwood dust, fixed by Italian law to 5 mg/m³ (Legislative Decree No 66/2000), is nearly complied with and, in most cases, the levels of exposure are lower than 2 mg/m³ (about 74% of exposures), as shown in figure 1. Workers in the building and repairing of ships and boats (NACE: 35.1) have a

Table 3 Arithmetic mean (AM), geometric mean (GM), geometric standard deviation (GSD) of exposure measurements of wood dust (mg/m³) by economic activity sector and job category, SIREP (1996–2006)

Activity sector* (NACE code)/job category† (ISCO-88 code)	No‡	AM	GM	GSD	5th centile–95th centile
Building and repairing of ships and boats (35.1)	**479**	**1.88**	**1.41**	**1.72**	**0.25–4.07**
Woodworking machine setters and setter-operators (7423)	287	1.98	1.55	1.49	0.38–4.10
Carpenters and joiners (7124)	103	1.44	0.96	1.81	0.25–3.80
Manufacture of builders' carpentry and joinery (20.3)	**1803**	**1.52**	**0.97**	**1.94**	**0.15–4.33**
Wood-processing-plant operators (8141)	89	2.48	1.65	2.84	0.10–4.50
Woodworking machine setters and setter-operators (7423)	964	1.79	1.26	1.96	0.25–4.33
Wood and related products assemblers (8285)	144	1.39	0.76	2.10	0.01–5.30
Wood-products machine operators (8240)	362	1.06	0.65	1.16	0.10–3.40
Manufacture of other products of wood; etc (20.5)	**1294**	**1.47**	**1.08**	**1.45**	**0.20–3.60**
Woodworking machine setters and setter-operators (7423)	567	1.55	1.11	1.46	0.16–3.88
Wood-products machine operators (8240)	459	1.41	1.08	1.45	0.30–3.10
Manufacture of furniture (36.1)	**4347**	**1.47**	**0.97**	**1.56**	**0.10–3.70**
Industrial robot operators (8170)	74	2.28	1.36	3.23	0.09–3.60
Wood-processing-plant operators (8141)	179	1.82	1.39	2.01	0.40–4.50
Basketry weavers, brush makers and related workers (7424)	68	1.56	1.12	1.75	0.21–4.83
Woodworking machine setters and setter-operators (7423)	2051	1.56	1.05	1.62	0.16–3.70
Wood and related products assemblers (8285)	414	1.38	0.83	1.77	0.10–4.02
Wood-products machine operators (8240)	1346	1.26	0.82	1.17	0.07–3.60
Sawmilling and planing of wood; impregnation of wood (20.1)	**1517**	**1.36**	**0.92**	**1.62**	**0.20–3.95**
Woodworking machine setters and setter-operators (7423)	828	1.61	1.15	1.80	0.23–4.10
Wood-processing-plant operators (8141)	64	1.32	1.01	1.18	0.50–4.01
Wood-products machine operators (8240)	345	1.18	0.80	1.44	0.10–2.90
Wood and related products assemblers (8285)	53	0.67	0.42	0.73	0.15–2.50
Manufacturing labourers (9320)	54	0.30	0.28	0.02	0.20–0.64
Manufacture of veneer sheets; manufacture of plywood, etc (20.2)	**426**	**1.05**	**0.79**	**0.60**	**0.13–2.44**
Woodworking machine setters and setter-operators (7423)	186	1.03	0.83	0.35	0.10–2.40
Wood-products machine operators (8240)	114	0.94	0.74	0.41	0.15–2.30

*The activity sectors with the highest and lowest arithmetic mean where at least 100 exposure measurements were available; †the job categories with the highest and lowest arithmetic mean where at least 50 exposure measurements were available; ‡number of TWA-8 exposure measurements.

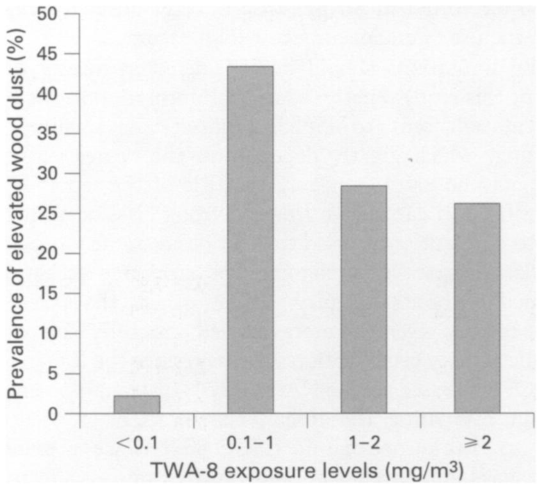

Figure 1 Prevalence of elevated wood-dust exposure by TWA-8 exposure levels.

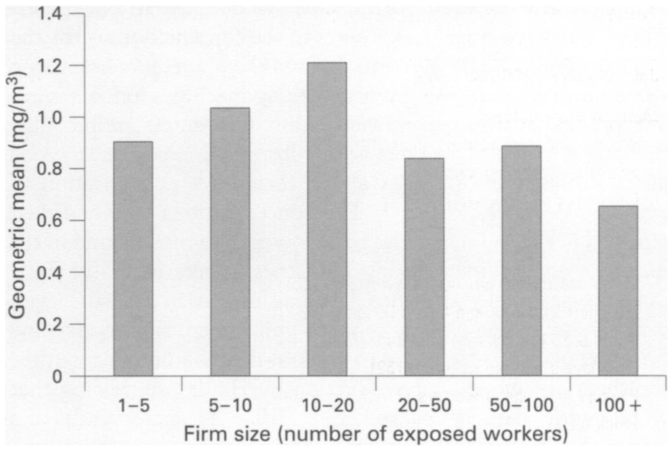

Figure 2 Geometric mean of exposure levels to wood dust by company size.

prevalence of elevated exposure levels >2 mg/m^3 two times higher (45.09%) than the prevalence among workers in the sawmilling and planing of wood (NACE: 20.1; 22.48%), and about five times higher than workers in the manufacture of veneer sheets and of plywood (NACE: 20.2; 9.62%).

One-way ANOVA showed that the variables most related to wood-dust exposure levels are job category ($\eta^2 = 0.046$; $\chi^2 = 656.35$ $p<0.0001$), geographical location ($\eta^2 = 0.035$; $\chi^2 = 463.30$ $p<0.0001$), activity sector ($\eta^2 = 0.031$; $\chi^2 = 493.32$ $p<0.0001$) and company size ($\eta^2 = 0.029$; $\chi^2 = 487.98$ $p<0.0001$). Exposure level increases linearly with company size for the first three classes and then decreases for the remaining classes (fig 2). The largest number of documents on exposures (above 58%) come from companies in north-eastern Italy (AM = 1.37, of which about 37% from the Veneto region) but higher exposures are experienced in companies located in the south and the islands (AM = 2.18). With regard to the degree of urbanisation of a company's site, the exposure level decreases for the first three classes (urban AM = 1.56; semi-urban AM = 1.39 and semi-rural AM = 1.18) and increases rapidly for the last class (rural AM = 1.96).

In the mixed effects model, variables significantly associated ($p<0.05$) with exposure in univariate analyses and all interactions (two by two) were analysed to test independent effects. Non-significant interactions ($p>0.05$) were excluded step by step from the model. The variables included in the final model and their statistical significance are reported in table 4. The fixed effects of the model explain 30% of the variance of observed exposure data, confirming univariate analyses findings after adjustment for other predictor variables. The most significant interactions result between activity sector and job category, followed by company size and job category. The main effects "activity sector" and "geographical area" are not significant in the final model. However, they are left in the model since significant interactions between other variables can mask their main effects.

DISCUSSION

Occupational exposure evaluation is a fundamental step in risk assessment and implementation of preventive measures for health surveillance in the workplace. In many cases the main issue is not the identification of exposure but the quantification of its magnitude. Over the past few years, exposure assessment methods,[21] job exposure matrix[22] and national databases[23–25] were developed in order to improve the quality and accessibility of exposure data. In this context, the SIREP database aims to facilitate analysis of occupational exposure figures for carcinogenic agents and to support data retrieval.

Wood dust seems to be the most frequent carcinogenic agent in occupational exposures recorded by SIREP,[18] confirming the results of an earlier European study that found this exposure widespread in the 25 member states of the EU. About 3.6 million workers (2.0% of the employed population) were

Table 4 Final mixed-effects model for wood-dust exposure*

Variable	DF	η^2	χ^2	F-test	p Value
Geographical area	3	0.001	7.31	2.44	0.0626
Company size	5	0.003	23.55	4.71	0.0003
Activity sector	44	0.004	34.27	0.78	0.8534
Job category	33	0.027	258.83	7.84	<.0001
Geographical area × company size	12	0.003	25.60	2.13	0.0123
Geographical area × job category	39	0.011	107.15	2.75	<.0001
Activity sector × job category	110	0.069	681.84	6.20	<.0001
Company size × job category	73	0.036	347.72	4.76	<.0001
Model					
Res log likelihood = −7927.0					
$\sigma_B^2 = 1.11$, $\sigma_W^2 = 0.18$†					
$R^2 = 0.30$‡					

*Mixed procedure in SAS software; †between-company and within-company variance; ‡fraction of the total variance explained by the fixed effects.

occupationally exposed to inhalable wood dust in the period 2000–3, with the highest exposures in the construction sector and furniture mills. The majority of workers were construction woodworkers, often using woodworking machines indoors without local exhaust or general ventilation. Carpenters are probably the largest group of workers with substantial exposure to wood dust, although information about their level and duration of exposure is poorly known.[12] The concentrations of wood dust reported in the sawmills tend to be lower than those found in the furniture and cabinet-making industries, where excess of nasal cancers was initially identified.[26] The differences in exposure levels between sawmills (which tend to mill green softwoods) and furniture plants (which tend to use kiln-dried hardwoods) outline the theory of wood-dust production by Hinds,[9] suggesting that wood with densely packed cells (that is, hardwood) and inflexibility features (that is, dry wood) is likely to shatter during processing, producing large amounts of particulate with low mass median diameters. A study performed by Demers *et al*[4] found a doubled risk statistically significant for sinonasal cancer in men employed in any wood-related job (OR = 2.0, 95% CI: 1.6 to 2.5) in comparison to men who had never worked in a wood-related job. The increased risk was reported among sawmill workers (OR = 2.5, 95% CI: 1.8 to 3.4), furniture workers (OR = 4.5, 95% CI: 3.2 to 6.5) and carpenters (OR = 2.9, 95% CI: 2.1 to 3.9), while no excess risk was observed among forestry, logging, pulp and paper workers. An increasing risk was observed in relation to the duration of exposure, and lagging exposure by 5, 10 or 20 years increased the strength of the association between duration of employment and sinonasal adenocarcinoma.

SIREP data on wood-dust exposures come mainly from companies related to the wood industry and furniture manufacture, while fewer data come from companies in forestry and logging, and in manufacture of fabricated metal products, which are sectors where exposure to wood dust is not directly associated with the onset of sinonasal cancer.[15] Among the economic activities most related to wood-dust exposure, the construction sector is hardly represented. Mean level of exposure seems to be highest among wood-processing-plant operators and the most frequent among woodworking machine setter-operators. The most common tasks in such job categories are wood shaving, cutting and wood treatments generally. Handicraft workers of wooden articles also have high exposure values. These results are consistent with those reported in other studies, though the classification systems used are somewhat differently structured.[27–31] In particular, the mean level of wood dust in the manufacture of furniture reported in our study (GM = 0.97, n = 4347) is similar (GM = 0.95, n = 2362) to that reported by Mikkelsen *et al*[32] in investigating determinants of wood-dust exposure in the Danish furniture industry.

Mean levels of exposure are higher in men than in women but the number of exposure measurements within the database is smaller for women (approximately one-fifth); therefore this finding should be interpreted with caution. The significant relation between mean levels of exposure and company size confirms a greater interest in prevention measures by medium and large companies than the small ones. Studies have usually found that company size has a significant effect on the degree of proactiveness, and larger organisations are more likely to adopt preventive health and safety practices[33] than small companies, which often lack specific experts in workplace safety.[34] Moreover, the pattern of exposure level by geographical area reflects the less advanced technological and industrial features of the south of Italy with respect to the more innovative north. Therefore, company size and geographical area are likely surrogates for other factors (not stored in SIREP) that directly influence exposure, such as the use of engineering control measures.[31]

Several limitations should be considered in interpreting the results of this study. Firstly, a lack of information in the original documentation sent to ISPESL. Indeed, the quality of the computing, which greatly depends on the degree of reported details, may be low when only the title of the report is given. Misclassification can derive from a wrong classification of jobs owing to different terms used to describe the same job. Secondly, some classifications (for example, the economic activity) were performed without difficulty, unlike others that were more difficult to code given the more detailed structure. Re-coding the economic activity classification was easy, since the Italian version (ATECO91) is based on the NACE Rev 1. Instead, problems were found in comparing the Italian classification of occupations (CP91) to the European one (ISCO-88),[35] since a translation activity was required, thus implying further misclassifications. In addition, most common errors were the misplacing, misclassifying or mistyping of information on the original data-sheet (for example, a job category miscoded with an economic activity, the wrong typing of an identification number or date, the use of not standardised classifications, etc).

Some potential bias of this study needs also to be discussed. The "exposure registers" excluded for lack of information (35%) seem not to induce selection bias, since no significant difference was observed between the distribution by economic sector and company size in the two groups (companies included and excluded from the analysis). The conservative hypothesis of assuming as a measure of exposure level the value originating from "the worst case exposure level" unlikely to overestimate our results since the repeated exposure measurements within the database are relatively few (about 7%). A possible selection bias could result from a smaller account of micro-companies (classes "1–5") in the SIREP database, as shown in the comparison with industry census data (in economic sectors where wood-dust exposure is widespread), since small companies are usually less directed towards adopting prevention measures.[33] Such distortion, if confirmed, would lead to an underestimation of the overall exposure levels. The number of companies and workers expected to be included in the SIREP database should be much higher if compared to a former evaluation of exposed workers to wood dust,[12] even if our data concern only hardwood dust. One reason for this discrepancy may be the difficulty in determining whether a worker is occupationally exposed to carcinogens, particularly when the exposure level is low, the amount of used carcinogen is small and in the presence of mixtures (for example, wooden boards). In a former study on occupational exposure to carcinogens in Finland, Heikkila and Kauppinen partially ascribed the difference found between reported and estimated figures to this reason.[36] Moreover, the possibility that companies not keeping and transmitting their exposure registry to ISPESL probably have higher exposure levels, might affect our estimates. This assertion may be confirmed only evaluating law firms' compliance with a specific survey. However, the large sample size used (which increases the precision of estimates) and the statistic model adopted (which accounts for both fixed and random effects) strengthen the results of the study.

Other problems inherent in the use of the administrative source SIREP are the original purpose of data collection (for example, complaint, compliance, research, etc), changes in measurement techniques and variability in environmental conditions, which may distort exposure measurements if not reported in the database.[37] Furthermore, details on control

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measures adopted (for example, general ventilation, enclosures, protective equipment, etc) are relevant as significant determinants of wood-dust exposures.[27] Thus, several factors may influence the level of occupational exposure, and missing the features of these factors imply an incorrect assessment of exposure determinants.[21]

Nevertheless, this study has several notable strengths. SIREP represents the largest source of data on occupational exposure to carcinogens in Italy, and may be useful in identifying high risk conditions of exposure. Administrative data sources used to assess exposure for epidemiological purposes usually include information on at least one job, often the most recent or usual job.[38] The large differences in the quality of occupational hygiene datasets, or the way they are used, are the most problematic issues in retrospective exposure assessment.[39] An occupational exposure database like SIREP may avoid these problems by taking into account the whole occupational history of each worker. The use of a job-exposure matrix or an indirect measure as a surrogate of exposure assessment may be replaced or updated with more specific and sensitive information. Furthermore, the use of ISCO-88 for job titles and NACE Rev 1 for economic activities as reference classifications is a strength point of this study, since these codes are suitable for international use and comparisons. Classifications of jobs and industries are frequently used tools in population-based studies, although their use is far from being standardised. Moreover, systematic and standardised collection of relevant information on exposure is important especially for rare cancers, when investigating retrospectively the whole occupational exposure history is difficult, given the long latency time of the disease. The latency period for nasal cancer (especially adenocarcinoma) averages 40 years,[40] and a decrease of the risk is not detected for at least 15 years after termination of exposure to wood dust.[29] Information on past exposures linked with data from population-based cancer registers can improve prevention and investigation of the aetiology of occupational-related tumours. The establishment of a national nasal cancer registry together with the training of hospital clinicians on diagnostic procedures would improve the identification of the occupational aetiology of this cancer site and the implementation of epidemiological studies.

Conclusions

This study confirms the previous findings about occupational exposure to wood dust (mainly in the wood industry and among woodworking machine operators) and suggests further investigations on other risk sectors (for example, building and repairing of ships and boats). Informative campaigns are strongly recommended, mainly for small and medium enterprises, which often lack the resources to develop proactive occupational strategies that go beyond minimum regulatory compliance, and thus scarcely deal with the implementation of advanced health and safety programmes in the workplace. The potential for administrative databases to provide useful information on occupational exposures is also demonstrated. This knowledge can be very useful in designing strategies for preventing occupational exposures.

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Main messages

- The establishment of an occupational exposure database in Italy enables us for the first time to have a large study on wood-dust airborne concentrations in a wide range of industrial sectors.
- The availability of a large dataset allows us to analyse some determinants of exposure levels and the use of international standard classifications facilitates comparisons between studies.
- The overall geometric mean of exposure levels to wood dust is 0.97 mg/m^3 and it is based on 10 837 exposure measurements.

Policy implications

Results stress the need to implement exposure hazard surveillance and give guidance on preventive measures.

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